



# GIS-Based Assessment of Methane Emission from Livestock in India



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## Abstract

Livestock farming is a major source of livelihood in India, but also a potential source of greenhouse gases (GHGs) emission, particularly CH<sub>4</sub>. The present research provides a detailed spatial livestock mediated CH<sub>4</sub> emission inventory covering all the districts and states of India. Results show, livestock CH<sub>4</sub> emission in India is 15.3 Tg yr<sup>-1</sup> with Banas Kantha (Gujarat) and Uttar Pradesh being the highest emission contributor at district and state level, respectively. Thus, monitoring and understanding spatial livestock distribution and its CH<sub>4</sub> emission pattern is essential for policy design to ensure sustainable livestock farming and effective climate mitigation policies.

**Keywords:** Livestock farming; GIS; CH<sub>4</sub> emission; Climate mitigation; India

## Introduction

Climate change is altering the world ecosystems and threatening the comfort of current and future generations. To control the temperature, rise below 2° Celsius as envisaged in the Paris climate deal and avoid risky climate change, halt in global emissions is immediately required. With these growing concerns of the detrimental impacts of climate change, identification and controlling of potential sources of greenhouse gases (GHGs) emissions has become an international priority [1]. Main contributors of anthropogenic GHGs are CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, where agriculture is a major source of emission for last two GHGs [2,3]. The livestock sector is considered as one of the major anthropogenic sources of GHGs emissions [4,5]. Livestock production and environmental impacts are facing unprecedented challenges due to the growing economy and rapid demand for meat and dairy products [6]. This will be an important issue in coming decades to reduce GHGs emissions from livestock sector and to support economic services in a sustainable way [7]. Within the livestock farming, milk and meat production contribute significant amount of GHGs emissions.

Enteric fermentative digestion by ruminant animals is the world's largest source of CH<sub>4</sub> emissions [8]. The specific digestive system of ruminant animals such as cattle, buffalo, sheep, and goat are associated with high levels of CH<sub>4</sub> production [9,10]. It is also estimated that 5.6–7.5 Gt CO<sub>2</sub>e GHGs yr<sup>-1</sup> is emitted annually by livestock sector between 1995 and 2005 where the most important sources of emissions were enteric CH<sub>4</sub> (1.6–2.7

GtCO<sub>2</sub>e yr<sup>-1</sup>) [11]. Among livestock group, cattle dominate (64–78%) the sector's emissions [11]. However, livestock contribute significant part of the livelihoods of at least 1.3 billion poor people in rural households [12]. Despite the importance of livestock to the poor and the magnitude of the changes that are likely to be fall on livestock systems, the intersection of climate change and livestock in developing countries is a relatively neglected research area [13]. Environmental legislation and public concerns about the environmental footprint of livestock production operations have increased pressure on producers to adopt measures to reduce atmospheric and environmental pollution [14]. Worldwide initiatives such as the Kyoto Protocol demand that GHGs emissions should be reduced or at least prevented from further increase [15]. Monitoring and understanding the distribution of livestock in relation to production system at various geographical scales is essential for designing intervention to ensure sustainability of livestock production [16].

India, the world's 2nd most populace country is also the world's 3rd largest GHGs emitter, contributing ~7% of the global total [17]. To be effective and least cost, climate policy requires the reduction of emissions of all GHGs [18]. It is reported that Indian livestock sector emits significant GHGs, particularly in the form of CH<sub>4</sub> [19,20]. In India, enteric CH<sub>4</sub> emission is high due to two main reasons: large number of ruminant densities over large area and poor feeding management [21,22]. The Paris climate

deal through its Intended Nationally Determined Contributions (INDC) also sought climate pledges from individual countries to devise domestic plans to reduce GHG emissions [23].

Assessment of GHGs emissions from the livestock sector and identifying the hot-spots of emissions as well as livestock population is pre-requisite for cost-effective emission reduction goals. The hot spot analysis can be helpful to minimize negative environmental impact of livestock production and design and implement more effective policy instruments for livestock farmers at different scales including local policy making. However, no assessment has been conducted in India to assess the geographical distribution of CH<sub>4</sub> emission from livestock at small spatial units up to district level. Furthermore, district level partitioning of emissions among the different livestock groups (cattle, buffalo, goat, and sheep) and CH<sub>4</sub> fluxes per capita and per geographical unit are also have not been previously

studied. Aiming to fulfill this research gap, the present research is conducted in India on GIS platform to (i) assess district and state level CH<sub>4</sub> emission from different livestock categories, (ii) per capita and per geographical area wise spatial distribution of livestock and CH<sub>4</sub> emission, and (iii) identify livestock-mediated CH<sub>4</sub> emission hotspots in India.

### Methodology

The methodology is divided into three sections as shown in Figure 1. In summary, estimation of CH<sub>4</sub> emission from livestock is based on the IPCC Tier 1 guideline [24]. The livestock population and CH<sub>4</sub> emission is estimated at district, state and national level. In addition to CH<sub>4</sub> emission, CH<sub>4</sub> flux per capita and per unit geographical area are also calculated. The findings are then applied in the GIS (Geographical Information System) platform to map spatial distribution of CH<sub>4</sub> emission in India.

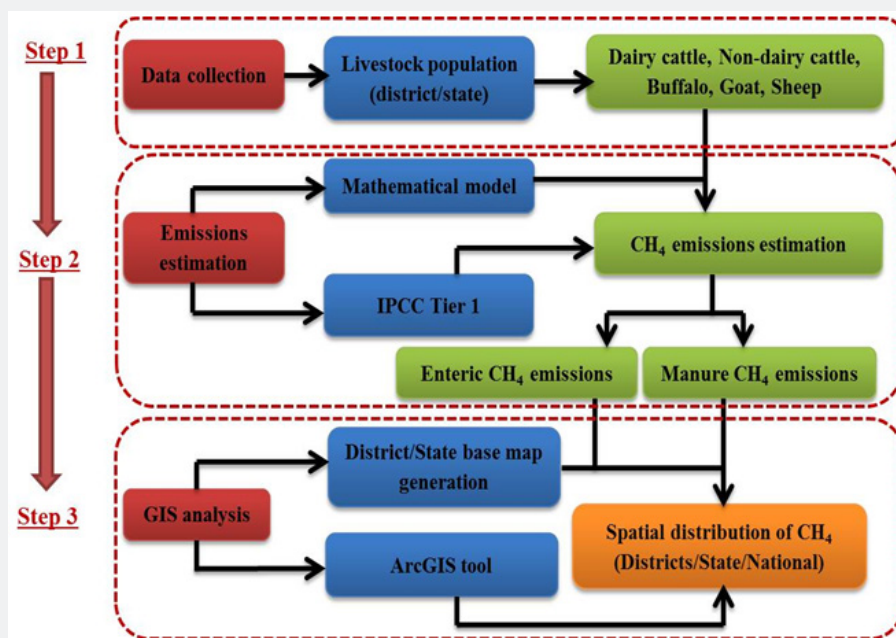


Figure 1: Flow chart of the methodology for estimation of spatial distribution of CH<sub>4</sub> emissions from livestock in India.

The first section of the method is comprised of livestock population database collection and associated CH<sub>4</sub> emission estimation. Livestock population database are collected from the Department of Animal Husbandry and Statistics, India for year 2012 [25]. The collected livestock database of all the 28 states and 7 UTs covering 649 districts of India is divided into four categories viz. cattle, buffalo, goat and sheep. CH<sub>4</sub> emission is

estimated from enteric fermentation and manure management practices. The specific CH<sub>4</sub> emission factor for each category of livestock as given in IPCC guidelines, 2006 (Table 1) both for enteric fermentation and manure management are used to further calculate livestock category-wise emission. Finally, the district-wise CH<sub>4</sub> emission are summed together to estimate state-wise and national-level CH<sub>4</sub> emission.

Table 1: Specific CH<sub>4</sub> emissions factor (kg CH<sub>4</sub> head<sup>-1</sup> yr<sup>-1</sup>) for different livestock categories.

Category		Enteric fermentation	Manure management
Cattle	Dairy cattle	58	5
	Non-dairy	27	2
Buffalo		55	4
Sheep		5	2
Goat		5	0.22

Per capita and per unit geographical area-based CH<sub>4</sub> emission flux are calculated for each district of India considering district-wise human population and geographical area data available from the Census of India, 2011 [26]. The district wise CH<sub>4</sub> emission fluxes are presented as GgCO<sub>2</sub>e CH<sub>4</sub> km<sup>-2</sup> and Gg CO<sub>2</sub>e CH<sub>4</sub> capita<sup>-1</sup>. In third step, ArcGIS software is used to generate the spatial CH<sub>4</sub> emission distribution map in India at district, state and national level. For a spatial map generation, standard images for different districts and states of India have been collected from the National Remote sensing Centre (NRSC), Government of India. Once the standard images of the district level map and state level map of India have been collected, CH<sub>4</sub> emission is categorized in to different rank to generate CH<sub>4</sub> emission. However, district level map is not available for Jammu and Kashmir. Therefore, it is represented at state level map.

### Results

CH<sub>4</sub> emissions from livestock (cattle, buffalo, goat and sheep) are estimated both from enteric fermentation and manure

management processes at district, state and national level in India and the results are presented below.

### CH<sub>4</sub> Emission at National Level

Overall, livestock CH<sub>4</sub> emission in India are estimated to be 15.3Tg CH<sub>4</sub> on annual basis considering 2012 livestock population data as baseline. CH<sub>4</sub> emission related to enteric fermentation and manure management are estimated to be 14.20Tg and 1.16Tg, respectively. Thus, it is observed that enteric fermentation contributes more than 90% of emissions. Among the livestock groups, in case of enteric fermentation, livestock category-wise emissions are 51% (7.25 Tg yr<sup>-1</sup>), 42% (5.97 Tg yr<sup>-1</sup>), 5% (0.68 Tg yr<sup>-1</sup>) and 2% (0.30 Tg yr<sup>-1</sup>) due to cattle, buffalo, goat and sheep, respectively. Similarly, in manure management practices, emission contribution of cattle, buffalo, sheep and goat are estimated at 0.59Tg yr<sup>-1</sup> (50%), 0.43 Tg yr<sup>-1</sup> (37%), 0.13 Tg yr<sup>-1</sup> (11%) and 0.03 Tg yr<sup>-1</sup> (2%), respectively (Figure 2).

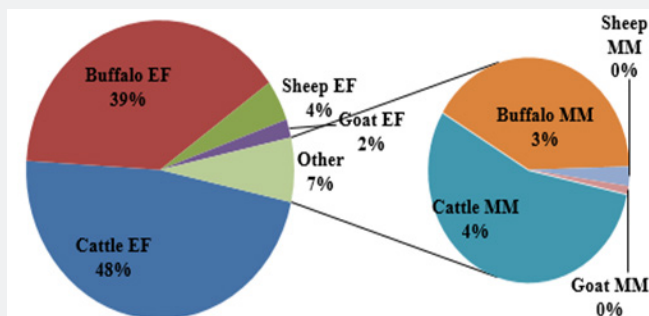


Figure 2: Category-wise CH<sub>4</sub> emission due to enteric fermentation and manure management (percentage distribution).

### CH<sub>4</sub> Emission at State Level

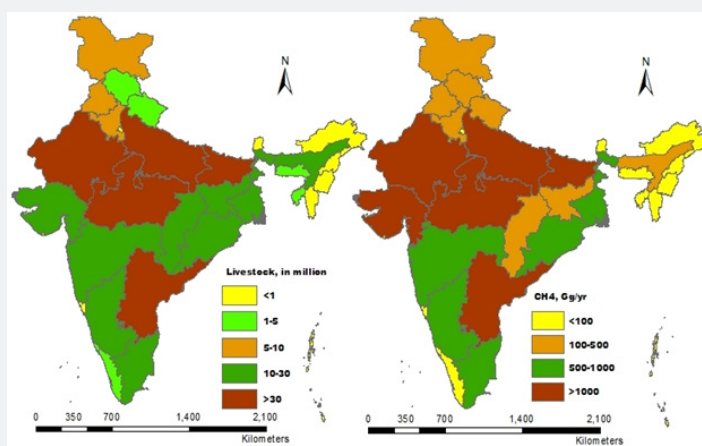


Figure 3: Livestock CH<sub>4</sub> emissions from different categories of livestock at district levels in India, (a) livestock CH<sub>4</sub> emissions from cattle sector from different districts, (b) livestock CH<sub>4</sub> emissions from buffalo from different districts, (c) livestock CH<sub>4</sub> emissions from sheep from different districts (d) livestock CH<sub>4</sub> emissions from goat from different districts.

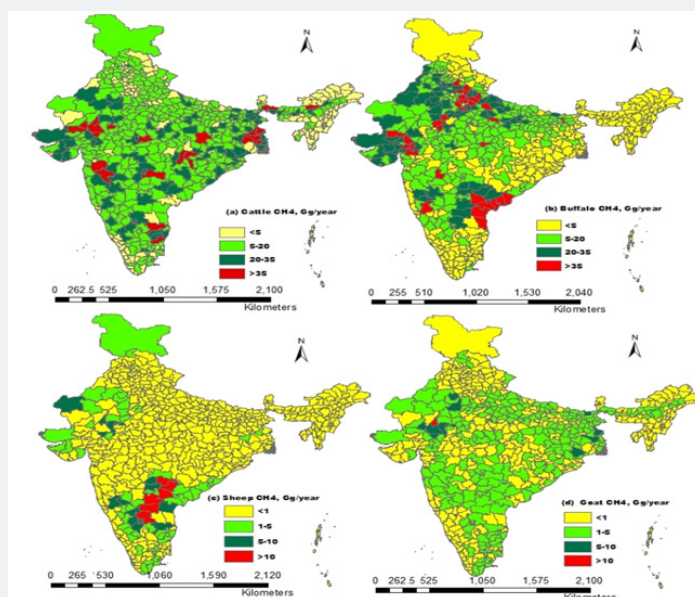
Among the 28 states and 7 Union Territories (UTs), the highest CH<sub>4</sub> emission is observed in Uttar Pradesh (2746 Gg yr<sup>-1</sup>), followed by Rajasthan (1528 Gg yr<sup>-1</sup>) and Madhya Pradesh (1310 Gg yr<sup>-1</sup>). Spatial distribution of livestock and associated CH<sub>4</sub>

emission among the states are shown in Figure 3. It is observed from Figure 3 that Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh and Bihar have annual livestock CH<sub>4</sub> emission greater than 1000Gg. It is also observed that major

emitting states are distributed in the western and Indo-Gangetic plains of India. In contrast, CH<sub>4</sub> emission contributions from all

the 8 north-eastern states are very less compared to other parts of the country.

**CH<sub>4</sub> Emission at District Level**



**Figure 4:** Livestock CH<sub>4</sub> emissions from different categories of livestock at district levels in India, (a) livestock CH<sub>4</sub> emissions from cattle sector from different districts, (b) livestock CH<sub>4</sub> emissions from buffalo from different districts, (c) livestock CH<sub>4</sub> emissions from sheep from different districts (d) livestock CH<sub>4</sub> emissions from goat from different districts.

CH<sub>4</sub> emission show significant variations among the districts of India as shown in Figure 4. The top 10 CH<sub>4</sub> emitting districts are listed in Table 2 with other relevant information. The top 3 districts in terms of livestock-related CH<sub>4</sub> emissions are Banas Kantha, Gujarat (112 Gg), Paschim Medinipur, West Bengal (103 Gg yr<sup>-1</sup>) and Jaipur, Rajasthan (102 Gg yr<sup>-1</sup>). Furthermore, out of

the total 15.3Tg livestock CH<sub>4</sub> emission in India, about 50% of the emission is contributed by 153 districts alone (out of total 649 districts). Within the 153 districts, out of the four livestock groups, maximum CH<sub>4</sub> emission (more than 50%) is contributed by buffalo in 84 districts followed by cattle (55 districts).

**Table 2:** Top 10 CH<sub>4</sub> emitting districts in India (emission values in Gg yr<sup>-1</sup>).

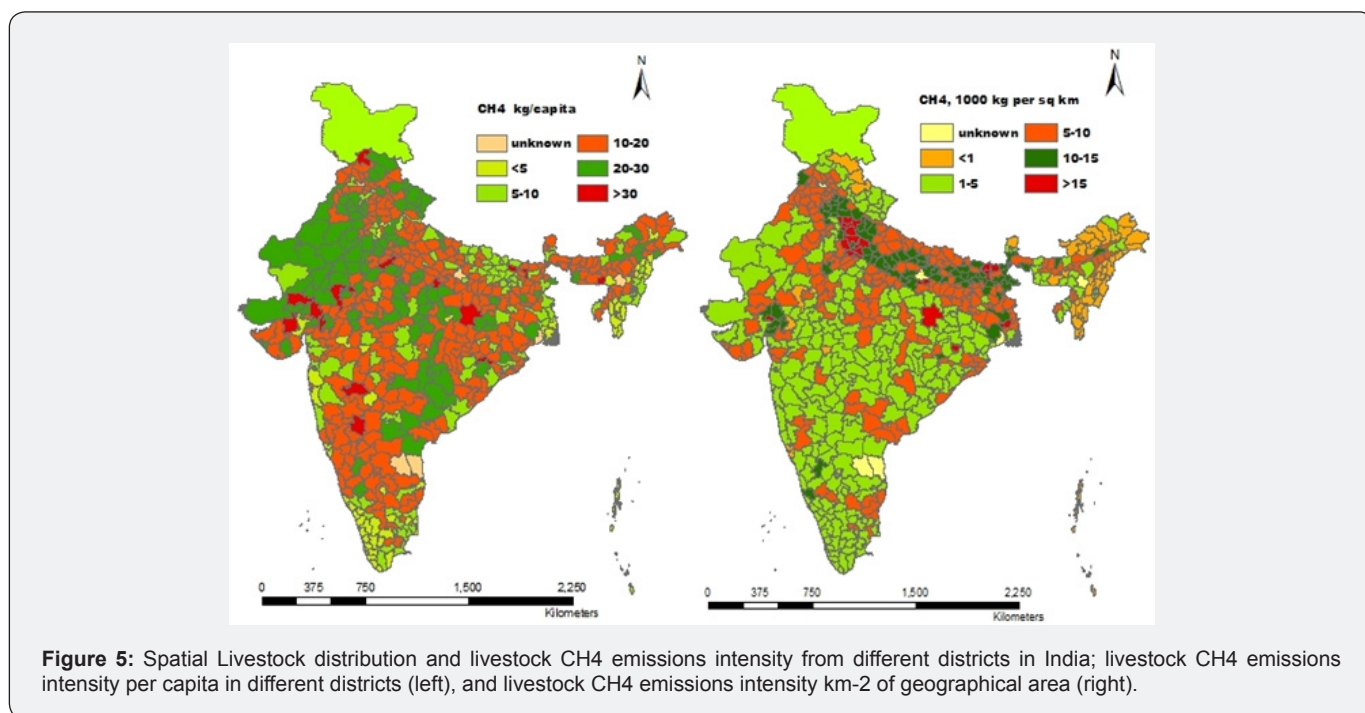
Livestock category	Top 10 CH <sub>4</sub> emitting districts	Livestock population	CH <sub>4</sub> emissions	CH <sub>4</sub> emission
			(Gg yr <sup>-1</sup> )	
Cattle dairy	Paschim Medinipur, Ahmadnagar, Bardhaman, Chittoor, Bikaner, Bankura, Jodhpur, Banas Kantha, Purba	48	305	Among the top 10 districts, the highest and lowest emissions of 46Gg and 24Gg from Paschim Medinipur and Raipur, respectively.
Cattle non-dairy	Medinipur, and Raipur			
	Paschim Medinipur, Bankura, Bardhaman, Raipur, Surguja, Durg, Ahmadnagar, Adilabad, Birbhum, and Nashik	123	250	Highest emission is from Paschim Medinipur (46Gg) and the lowest emission is from Nashik (20Gg) anthe top 10 districts.
Buffalo	Bulandshahr, Banas Kantha, Aligarh, Jaipur, Alwar, Guntur, Prakasam, Agra, Bharatpur, and Belgaum	10	604	Among the top 10 districts, the highest and lowest emission is from Bulandshahr (74Gg) and Belgaum (49Gg) respectively.
Sheep	Anantapur, Mahbubnagar, Nalgonda, Warangal, Karimnagar, Kurnool, Prakasam, Barmer, Y.S.R., and Chittoor	20	139	Among the top 10 districts, the highest and lowest emission is from Anantapur (28Gg) and Chittoor (9Gg) respectively.

Goat	Barmer, Jodhpur, Jaisalmer, Nagaur, Paschim Medinipur, Mayurbhanj, Udaipur, Murshidabad, Sikar, and Bardhaman	14	74	Highest and lowest emission is from Barmer (15Gg) and Bardhaman (5Gg) respectively among the top 10 districts.
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In case of cattle sector, Paschim Medinipur (West Bengal) shows the highest emission (91 Gg yr<sup>-1</sup>) among the districts in India. Similarly, at district level in buffalo, goat and sheep sectors, the highest CH<sub>4</sub> emission are observed in Bulanshahar, Uttar Pradesh (73 Gg yr<sup>-1</sup>), Baran, Rajasthan (15 Gg yr<sup>-1</sup>) and Anantpur, Andhra Pradesh (27 Gg yr<sup>-1</sup>), respectively. Thus,

this detail GIS-based representation of spatial distribution of livestock CH<sub>4</sub> emission reveals that the highest emitting districts (emission > 50% of total CH<sub>4</sub> emission) located in the states of Uttar Pradesh, Gujarat, West Bengal, Rajasthan, Andhra Pradesh, and Maharashtra (Table 2).

### Spatial Distribution of Per Thousand and Per Unit Area Livestock CH<sub>4</sub> Emission



**Figure 5:** Spatial Livestock distribution and livestock CH<sub>4</sub> emissions intensity from different districts in India; livestock CH<sub>4</sub> emissions intensity per capita in different districts (left), and livestock CH<sub>4</sub> emissions intensity km<sup>-2</sup> of geographical area (right).

Results of district level spatial distribution of livestock and CH<sub>4</sub> emission in terms of per geographical area and per thousand human populations is discussed below. At country average, CH<sub>4</sub> emission per sq km of land area is 6.02ton km<sup>-2</sup>. At district level, the CH<sub>4</sub> emission intensity ranges from the lowest of 1.8 × 10<sup>-3</sup>ton km<sup>-2</sup> in Dibang Valley district of Arunachal Pradesh to highest of 42.35ton km<sup>-2</sup> in Gandhinagar district of Gujarat (Figure 4). For nearly 38% of districts (more than 250 districts), the emissions intensity lies in the ranges of 1ton km<sup>-2</sup> to 5 ton/km<sup>-2</sup> as shown in Figure 5. These districts are mainly located in Maharashtra, Madhya Pradesh, Orissa, Kerala, Rajasthan, and Tamilnadu and in some cases in Sikkim, Manipur, Assam. The maximum emission intensity (> 15ton km<sup>-2</sup>) is observed in 20 districts of India.

At country average, per capita CH<sub>4</sub> emission in India is 12.71 kg capita<sup>-1</sup>. At district level, the intensity ranges between the lowest value of 2.4 × 10<sup>-2</sup> kg capita<sup>-1</sup> in Delhi and highest of 119 kg capita<sup>-1</sup> Surajguja district (Gujarat) (Figure 5). Maximum numbers of districts (250 districts) falls in the emission

categories of 10-20 kg capita<sup>-1</sup> (Figure 5). These districts are in the Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and some of the districts of Punjab, Rajasthan, Manipur, and Assam. On the other hand, the highest emission of > 20 kg capita<sup>-1</sup> is observed for 16 districts.

It is observed that livestock farming is highly dynamic in India. The higher livestock CH<sub>4</sub> emission regions are distributed along the middle gangetic plain, central plateau region, east coastal plains and western dry regions comprising some highly emission intensive districts and states (Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamilnadu). Livestock farming plays an important role in the economy of these states and districts. For example, in Rajasthan, more than 80% rural families linked with livestock farming and livestock farming contribute about 9.16% to the state GDP which is even greater than the national average GDP (~4%). Furthermore, about 35%-50% of the income to small and marginal farmers comes from the dairy and animal husbandry sectors. In Gujarat, about 5.19% state GDP is contributed by livestock. Considering

the immense contribution of livestock farming to the rural economy of India, therefore, future livestock policies should deal CH<sub>4</sub> emission reduction and sustainable livestock farming simultaneously and appropriately.

### Conclusion

This study identifies that 50% of emission is contributed by 153 districts alone out of 15.3Tg. Major findings are

- a. Cattle and buffalo are the major CH<sub>4</sub> emitter (93%) than other livestock groups.
- b. The top CH<sub>4</sub> emitting states are Uttar Pradesh, Rajasthan and Madhya Pradesh.
- c. The top emitting districts are Banas Kantha, Paschim Medinipur and Jaipur.
- d. CH<sub>4</sub> emission intensity is 6.02ton km<sup>-2</sup> and 12.71 kg capita<sup>-1</sup>.

Thus, livestock CH<sub>4</sub> emission spatial distribution indicate the hotspots region of emission and these findings can be useful to develop districts or state level policy for sustainable livestock farming.

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